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Eco-System Services and the Circular Economy for Textiles

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ECO-SYSTEM SERVICES AND THE CIRCULAR ECONOMY FOR TEXTILES

Abstract: The concept of industrial ecology has made important contributions to sustainable manufacturing. The discipline majored on applications of systems theory and modelling flows of materials energy and information. However, recognition of the importance of management and policy issues has moved thinking towards industrial ecosystems. This provides the context for interest in the circular economy (CE). The aim of this research, which emerges from the EU-funded Resyntex project, is to appraise the potential for CE in textiles to supplant the present linear supply chains where discarded materials end up in landfill or incinerated. There are major challenges adding value to textile wastes, especially as the materials are mostly from commodity products where price competition is intense. Preliminary work suggests that the business case for CE technologies and processes is not strong enough to attract potential investors. The research reported here draws on the concept of industrial ecosystem services to identify benefits not normally costed when making a financial appraisal. Some of these services can be measured financially, whereas others are indirect and can only be quantified by incorporating policy-related assumptions. However, when textile ecosystem services are quantified and incorporated into the business model, the outcome for CE is considerably more healthy.

1. Introduction

1.1 Background for sustainability thinking in industrial ecology and industrial ecosystems

The financial appraisal of manufactured products of most companies involves the externalising of some costs. These are costs that are carried by governments or local authorities, or even by companies that do not charge for the service provided (such as new product development). Environmental costs have a significant history of being externalised. The UK, along with many other countries, has addressed the issue by introducing environmental regulation: with legislation to clean up contaminated land, to improve air quality and to promote the principle that the polluter must not externalise costs but must pay for pollution incurred above specified limits.

In the textile industry, dyers and finishers were prime targets for this legislation. Without safeguards, rivers were selected as the means of taking away unwanted wastes. The chemicals discharged killed wildlife and plants, and the waters were coloured by unfixed dyes in the effluent. In the 1980s, some companies installed water treatment plants, but many more closed their UK operations and moved production offshore, where river waters were still unregulated and the polluter did not have to pay. Those companies still operating in the UK are typically low volume, niche producers of products that have a higher value that allows the operation to be profitable.

Much of the contemporary environmental legislation emerges from the EU. As well as the principle “The polluter pays”, there is an increasing application of “extended producer responsibility” to take back and dispose of products that have come to the end of their useful lives. This has been most evident in WEEE regulation: the Waste Electrical and Electronic Equipment Directive, first introduced in February 2003 (European Commission, 2018). Although the measures can be regarded as punitive, their effects have included many positive

outcomes: extensive use of Design for Environment and Design for Disassembly tools, the increased recycling rates of components and materials, and the development of a professionally-led recycling industry.

With globalisation, avoiding environmental costs ran alongside avoiding employment costs (in the UK: Health & Safety at work, employer contributions to the National Health Service and to pensions). Sourcing in low labour cost countries was equivalent to externalising the social costs of employment, as well as achieving reductions in direct costs. In these countries, health provisions were either non-existent or rudimentary, and state pension systems were not operating. The situation was justified, in general, by pointing out that the lower costs attracted inward investment and brought employment opportunities to both men and women.

Despite numerous initiatives to promote ethical trade and sustainable manufacturing, the situation is far from satisfactory. There are regular reports that indicate ongoing problems of exploitation, and other evidences that environmental policies are being flouted. The problems appear to arise mainly with 2nd and 3rd tier suppliers, and the response of brands is often to withdraw. Evidence for a desire to build long-term sustainable retail systems is shown by “Asda, Matalan and Next recently pulling orders from suppliers in India and Indonesia after reports they were significantly polluting their local areas.” (Clark, 2018)

These problems are, of course, not exclusive to the clothing and textile sectors. Many industries have had to grapple with similar scenarios. Some have recognised that a more fundamental change is needed in the way businesses operate in the world - and “Industrial Ecology” was born. Instead of treating “care for the environment” and “social ethics” as separate problems that need to be audited and policed, these issues are considered to be an integral part of a larger industrial ecosystem. According to Korhonen et al. (2004), “the metaphor of sustainable natural ecosystems [has been taken] as a model for transforming unsustainable industrial systems.” The manufacturing process, the supplier companies, the environment and the human community are treated as an inter-related holistic system. A systems approach to management is needed, and within this alternative paradigm (Ehrenfeld, 2000), strategies to avoid or externalise social and environmental costs are perceived as poor practice (leaving individuals, communities and governments to pick up the bills). This is the context for interest in the Circular Economy.

1.2 The Circular Economy as a new integrating paradigm

The trigger for paradigm change was the realisation that whatever sustainability initiatives were introduced, textile products end up either in landfill, or in an incinerator. The costs of disposal were rising rapidly. The question has to be asked - why are we spending money to dispose of these materials instead of redirecting the finances to turn waste into something that has value?

The Circular Economy is a zero-waste scenario. What is currently waste and valueless needs to be turned into a resource that has value. Wastes are created at all stages of the textile pipeline: fibre, yarn and fabric production; clothing manufacture; and at the end of a product’s life. Industrial wastes and consumer wastes both need to be addressed by adopters of circular economy principles.

To achieve any significant impact, Circular Economy implementers need to develop a systems approach to analysing the problems and finding solutions. This is likely to mean looking beyond traditional supply chains and finding ways of recycling and reusing materials that would otherwise be discarded as waste. It is this approach that links the Circular Economy closely with Industrial Ecology.

The new paradigm, however, extends the boundaries of the textile and clothing ecosystem. Consumers and retailers are perceived to be an essential part of the system. Their choices affect the goods offered to the market and the products actually entering the market. Also, their practices affect the way discarded garments are collected.

Market forces also affect the options for transforming waste into resources. Mechanical deconstruction of textile materials has been with us for many years, but the supply of discarded materials far exceeds demand for products manufactured from recycled fibres. Often, there are quality and design issues (fibre lengths are too short; residual colour in the fibres limits design options and consumer acceptance). In all cases, cost is a constraint, as virgin materials are relatively cheap and the reprocessing costs of used materials impose limits on commercially viable options.

For the above reasons, attention has focused on the chemical reprocessing of textile materials, leading to products that are not necessarily targeting the textile sector.

1.3 Resyntex as a Circular Economy initiative

Most initiatives to evaluate the chemical processing of textile fibres have focused on one or two fibre types (polyester, polyester/cotton, cotton, wool). However the Resyntex project (Resyntex, 2018) considers four categories of polymeric fibre: cellulosic, protein, polyester and polyamide. The conceptual model involved a sequential process that selectively removed polymer types and minimised the problems associated with products made from blends.

The project is funded by the European Union's H2020 programme and runs from June 2015 to November 2018. Resyntex is the first European wide initiative that integrates the whole value chain from textile waste collection to recycling to deliver a range of chemical feedstocks. It builds on the experience of 20 partners who are already linked to existing national networks that promote and develop textile recycling.

Resyntex addresses the recycling issue through two broad aims:

- To provide new valorisation routes for textile waste (e.g. transformation into high value and more competitive feedstock for chemical industries);
- To integrate the whole value chain and demonstrate a realistic Circular Economy pilot plant, supported by a viable business model adapted to new markets, and also to help citizens understand that their used clothes are not waste but have a recycling value (with significant impact on the environment).

The business modelling research feeding into the Resyntex project provides the foundation for the work reported in this paper. To assist focus, only the processing of cellulosic fibres is considered here.

1.3 The concept of Ecosystem Services applied to textile/clothing supply chains

Korhonen et al. (2004) pointed out that “the metaphor [of sustainable natural ecosystems] is a source of inspiration and creativity in the transformation of management and strategic visions towards a new sustainability culture.” Consequently, concepts emerging from a study of natural ecosystems may be relevant to industrial ecosystems. One of these concepts is that of “Ecosystem Services”, which are concerned with the benefits people obtain from ecosystems. It is usual to classify these as (a) provisioning services (e.g. the provision of food and water); (b) regulating services (e.g. flood and disease control); (c) cultural services (e.g. aesthetic and recreational benefits) and (d) supporting services (e.g. soil formation and nutrient recycling). These categories help the general public to appreciate the diversity of benefits that come when humans act as stewards of the environment.

Any appreciation of services provided by the environment deserves to be followed by the recognition that a value can be put on those services. This is the basis for working out how much the polluter ought to pay for damaging the environment and disrupting social life. An attempt to do this globally was undertaken by Costanza et al. (1997), who estimated that the value of these services are larger than the global gross national product.

Industrial ecosystem services do not have a high profile at present, and many people may not have appreciated that there are any benefits at all. One of the purposes of this paper is to articulate those services that derive from the textile ecosystem, and to suggest that people should not only recognise, but also to value, these benefits. Of course, Textile Ecosystem Services can be expected to highlight a rather different spectrum of benefits from Environmental Ecosystem Services, and this is considered further in Section 3 of this paper.

2. Business modelling of the CE Textile supply chain

The business modelling approach in this research uses financial appraisal to simulate the effects of introducing EPR-related discounts for recycling waste textiles, based on an estimated textile waste disposal fee structure for textile manufacturers. The aim of the model is to quantify how this may improve investment attractiveness for new recycling technologies such as Resyntex, particularly as they require considerable capital investment to scale-up operations to recycle the quantities of textile waste available. This means that payback periods are often extended, increasing the risk associated with investment. Thus, a strong strategic and financial case must be presented to support investment decision making (Chan et al., 2001)

The financial appraisal model uses known capital and operational costs extracted from the Resyntex project’s cost analysis and Life Cycle Costing (LCC) measured against estimated revenues based on market research and production capabilities over a twenty-year period. The model examines one of Resyntex recycling processes, reprocessing of protein-based fibres (Protein Fibre Hydrolysis to Peptide), pre-sorted and decontaminated prior to Resyntex chemical recycling. This process was selected for consideration here because it produces a high-value feedstock that has good market potential.

For the purposes of this research, the investment appraisal model outputs one key investment indicator within capital budgeting calculations, the break-even point, the level at which

revenue and operational and capital costs make neither profit or loss (Lumby & Jones, 2000). The model seeks to illustrate the effects of introducing EPR-related discounts on the processing cost of recycling waste textiles and how this may improve investment attractiveness by reducing the time it takes to break-even.

Within the model, there are key variables and assumptions that affect results. Firstly, the peptide feedstock (commodity for revenue generation) is set at an average price based on current market conditions that increases 2% per annum, based on consistent demand, and assumes the sale of 100% of the outputs. The yield of the recycling process (the rate of commodity produced per tonne of waste textile input) is also fixed and does not account for improvements in recycling efficiency. Capital and operational costs are not detailed in this paper as they are confidential, and the model is produced to illustrate the effects of EPR on the overall investment model only.

3. Analysis of Textile Ecosystem Services

It is inevitable that the services provided by an industrial ecosystem are distinctive and should not be expected to map directly across to equivalent environmental services. The primary rationale for a textiles circular economy is that it delivers Provisioning Services, providing economic benefits to society. The potential economic benefits outlined at the outset of the Resyntex project are identified in Table 1, to which other economic returns are likely to be added to the list, depending on technologies used and the price the market offers.

The second category of benefits obtained from the Textile Ecosystem is the provision of Environmental Services. It is essential that Circular Economy processes bring benefits for the environment. Existing initiatives to reduce the use of toxic chemicals will continue, as will also efforts to prevent non-biodegradable fibre fragments entering the biosphere.

The industrial ecosystem interacts closely with human society and personal lifestyles. Two categories can be distinguished here: Cultural Services providing non-material benefits to individual citizens, and Societal Services that provide benefits for communities. Cultural services incorporate significant educational elements that promote lifestyle changes (when garments are purchased, when in use and when they are disposed). Societal services relate to the use of resources, the opportunities for employment, and the promotion of innovative approaches at a local level. Specific examples are given in Table 1.

The crucial question is whether a value can be placed on these services. Should the Provisioning Services be expected to fund all the initiatives required to implement the Circular Economy? If the answer to this question is “Yes”, then what are the drivers for change to achieve the benefits associated with Environmental Services? In a price-sensitive industry, how can we achieve the desired reductions in pollution and the use of toxic chemicals when the experience of globalisation is that price advantage takes precedence over environmental stewardship? A similar point can be made about ethical sourcing, and the constant battle to prevent exploitation of labour to achieve the margins set by brand owners.

Table 1: Analysis of Textile Ecosystem services

Category	Benefits
Provisioning services (economic benefits)	<ul style="list-style-type: none"> • Feedstocks for adhesives • Feedstocks for fibres • Feedstocks for PET bottles • Feedstocks for food packaging • Feedstocks for biofuels
Environmental services (benefits for the environment)	<ul style="list-style-type: none"> • Reduction of toxic chemicals in dyeing and other textile processes • Reduction of toxic chemicals generated by incineration • Reduction of non-biodegradable fibre fragments • Reduction of contaminated land associated with landfill
Cultural services (non-material benefits for human lifestyle)	<ul style="list-style-type: none"> • Educational benefits re laundering/care • Educational benefits re textile ecosystem/disposal/waste2resource concept • Promotion of upcycling (personal fashion/cooperatives/SMEs) • Heightened awareness of ethical sourcing • Promoting a participation culture • Reduction of the values/action gap
Societal services (benefits for society)	<ul style="list-style-type: none"> • Reduction of need for landfill • Reduce dependency on primary resources • Stimulus for employment in domestic industry • Strengthen continuity of supply (of feedstocks) • Reduction of imported goods • Land used for biofuel (and cotton) released to grow food • Promoting innovation in use of discarded materials

4. Re-running the model with Ecosystem Services

The principle of Extended Producer Responsibility has been operational within the EU for WEEE products, and this has led to a significant increase of recycling and recovery of materials. Alongside this has been the use of design tools to incorporate the challenges of recycling into the product development process. In France, the EPR approach has been applied to the textile/clothing sector since 2006.

French companies producing and importing clothing, linen and footwear are responsible for managing the process of reuse and recycling of their products. There are two options

available to companies. They either contribute financially to a state-approved collection and recycling system or they manage their own collection and recycling system.

Eco-TLC is a private non-profit company accredited by the French government to manage the collection and recycling responsibilities of producers of clothing, linen and footwear (TLC in French). Members pay an annual contribution to Eco-TLC, based on the numbers of garments sold in the past year. There are different rates for different sizes of garments and there are discounts for products with a minimum of 30% pre-consumer recycled fibres. A listing of the four garment types and the current contribution rates are in Table 2.

Table 2: Eco-TLC sizes for clothing and household linen

Category	€ excl.VAT
Very Small Item (TPP)	0.00132
Small Item (PP)	0.00528
Average Item (MP)	0.00791
Large Item (GP)	0.05280

It is of interest to express these figures as € per tonne, as this is the requirement for a chemical recycling process. A source providing data on garment weights is Choi & Lee (2009), and the Eco-TLC categories can be matched as follows:

TPP – Category 1 (undergarments)	Mean 89g, SD 52g
PP – Category 2 (blouse, shirt, t-shirt)	Mean 200g, SD 121g
MP – Category 5 (Trousers, jeans)	Mean 438g, SD 150g
GP – Category 4 (Coat, jacket, jumper)	Mean 890, SD 456g

These figure are converted to €/tonne as follows:

TPP has 11236 garments in 1 tonne,	with a contribution of €14.80
PP has 5000 garments in 1 tonne,	with a contribution of €26.40
MP has 2283 garments in 1 tonne,	with a contribution of €18.06
GP has 1123 garments in 1 tonne,	with a contribution of €59.33

For preliminary modelling, we have used producer responsibility payments for wool products ranging from €20 - €60 per tonne. This levy on products has a small but significant effect on the financial analysis.

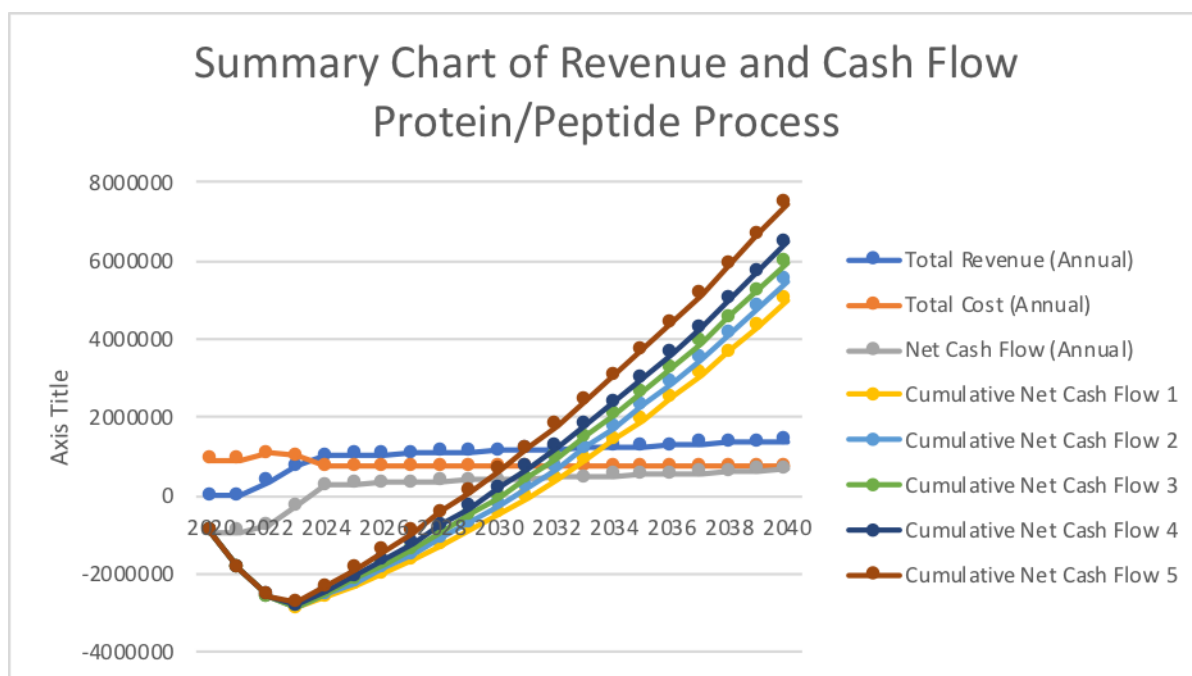
The EPR discount model (Figure 1) shows five models. The first is the original processing cost of recycling protein fibres, per tonne. The subsequent models discount based on different EPR charges, that are assumed to directly discount the processing cost. The final model simulates a matching for the cost per tonne for disposal by incineration of landfill in the UK, based on current standard rate of €102 per tonne (Environmental taxes, reliefs and schemes for businesses: Landfill Tax, 2018) and converted to Euros at the current exchange rate. The final row in Figure 1 shows the year when the investment breaks-even.

Figure 1: Summary of EPR discount rates and break-even year.

	Model 1: No Discount	Model 2: EPR €20	Model 3: EPR €40	Model 4: EPR €60	Model 5: Landfill or Incineration
Discount (Per Tonne)	n/a	€ 20.00	€ 40.00	€ 60.00	€ 102.00
Processing Cost (Per Tonne)	€ 183.82	€ 163.82	€ 143.82	€ 123.82	€ 81.82
Break-even Year	2032	2031	2031	2030	2029

A summary of the simulations run on the five models is shown in Figure 2 that plots the cumulative net cash flows of each model against operational costs and estimated revenues within the chosen recycling process and how the different discounts shown on the EPR model effect the break-even point, and, therefore, the investment attractiveness. It can be seen that matching costs of recycling a tonne of textile waste with current landfill and incineration taxation in the UK improves the break-even point by four years (Cumulative Net Cash Flow 5).

Figure 2: Summary graph showing EPR discount effect on cumulative net cash flow in each model.



In summary, capital budgeting techniques have been used to create a real model of investment appraisal for the Resyntex chemical recycling processes. The operational costs

and capital investment are currently high, based on the need to pioneer recycling facilities, with requirements to collect, transport, pre-sort and decontaminate input waste textile prior to processing as well as the cost of the chemical processing itself. To incentivise investment in sustainable technologies that support transition to the Circular Economy, EPR concepts provide a model that could effectively externalise some costs for establishing improved textile recycling infra-structure, thereby making the new technologies a more attractive financial prospect.

Modelling work is continuing with the processing of cellulosic, polyester and polyamide materials. In these cases, energy costs are higher and the feedstocks produced appear to have a lower value, so making the case for investment is more difficult. As the Resyntex project develops, the models will be refined – but the case for putting a value on industrial ecosystem services by requiring an EPR contribution from producers would appear to be very strong if the Circular Economy in textiles is to become a reality.

5. The prospects for Circular Economy implementation

France has led the way in implementing a scheme that introduces retailers and brand owners to the principles of Extended Producer Responsibility. Delegation of these responsibilities to Eco-TLC has met with numerous success stories, and the list of recycling schemes is impressive. However, there is a down-side, in that Eco-TLC does not have the resources to transform the landfill/incineration statistics, and the need for design to take into account end-of-life scenarios is largely unmet. Nevertheless, there is a financial incentive to incorporate some recycled fibres into textile products.

There is current discussion of new business models that incorporate Circular Economy thinking. Often, initiatives are taken by small companies motivated by vision, but establishing the viability of these new business models is challenging. Often, there is not enough money to generate further growth. The theme of alternatives to traditional retail sales is addressed in a recent Ellen MacArthur Foundation report (2017, p. 73):

To disrupt the current linear pathway for clothes, new models to access and maintain clothes are essential. Models that are not centred on ownership are needed to address fast-changing needs and styles (e.g. clothing rental). Models that explicitly offer high quality, great fit and additional services are needed to respond to segments that value durability (e.g. sales with warranties, clothing-on-demand, clothing resale, or repair services). Economic opportunities already exist for many of these models, and brands and retailers could exploit these through refocused marketing. These models would also lead to the design and manufacture of clothes that last longer, which could be further supported by industry commitments and policies.

Whilst these ideas have the potential to move companies towards the Circular Economy, there is still the problem of what happens to worn-out materials.

Most of the literature on designing for sustainable fashion is concerned with waste reduction during manufacture, moving from fast to slow fashion, using biodegradable materials and finding ways to reduce the use of toxic chemicals, energy usage, water usage and improve the carbon footprint. There is much less on designing for reuse, upcycling and recycling. Designing for the Circular Economy really needs the catalyst of a viable commercial process

to transform discarded textile materials into feedstock that can re-enter the economy rather than be landfilled or incinerated.

This is where Resyntex can close the loop and act as the needed catalyst for changing the supply chain paradigm. With chemical processing, waste can be transformed into resources. The processes can be more efficient if the industrial sector adopted Circular Economy design principles, including Design for Disassembly. However, the residual textiles in people's homes are not designed with chemical processing in mind, so it will be some time before Design for CE can reduce reprocessing costs.

The Resyntex business model described above has incremental changes to costs. Modest increases are envisaged for virgin fibres and for energy. However, it is possible that the cost of cotton will rise more rapidly than expected; that energy costs will rise dramatically; that landfill costs will soar. These changes may trigger change, as the economics of reprocessing triggers a tipping point. Waiting for the tipping point is a high risk strategy, as the infrastructure for reprocessing textiles will only be developed over a timescale measured in decades. The case for Extended Producer Responsibility is based on industrial Ecosystem Services, not the desire of governments to raise taxes. There are too many instances of externalising and avoiding the true costs of producing goods, and it is unjust not to rectify this situation. There will be new benefits: EPR policy encourages the new synergies, partnerships, joint-ventures and cooperation between industries. These are urgently needed to develop Circular Economy practices and business models that generate new revenue streams with an emphasis on valorising waste.

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